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My goal when first applying for the CAPSULE program was to integrate a full capstone project into my AP Physics class. I noticed students had no problem learning and using equations and concepts to solve even the most difficult problems on unit tests, but would stumble when given a comprehensive test. I believe introducing a significant open-ended problem such as a capstone project will lead them to change their thought process and give them the ability to identify and clearly define a problem. Nearing completion of the program, I have expanded my goals to bring more EDP based projects and capstone-like experiences to all levels I teach in addition to my original goal at the AP level.

Context

The classes I teach include two levels of 11th grade physics (class sizes from 21 to 29 students) and one AP Physics C: Mechanics class (10 students). Because physics is a required class for all 11th grade students, my students have a wide range of capabilities and previous knowledge they have obtained from other classes. My college preparatory classes consist students who are average, borderline honors, bright but never pushed to work to their potential, and even a few with special needs. My honors classes are more homogeneous with the range consisting of students who may only be borderline honors students to those who could have probably jumped straight to the AP level if that option was offered. This will be the second year that we have taught a comprehensive physics course to junior students after switching from a conceptual physics course for freshmen. As such, we have only planned out a rough curriculum and this year will be a trial run of sorts for that curriculum. This will also be the first year that the AP level students will have had a comprehensive algebra/trigonometry based physics course the year prior to taking the AP course.

Besides the make-up of my classes, the biggest barrier I have to deal with is the curriculum in place. While new curriculum does give me an opportunity to insert additional projects or units not currently in the place, I do still have to attempt to cover a set number of topics by the end of the year. In AP physics, the curriculum is set by the exam and I cannot skip any material and replace it with a project or additional units. Because I am only teaching the mechanics portion of the course and my students took physics last year, I should have time to work in the extra projects, but I have no way of accurately predicting the amount of time the class will have at this time.

Action Plans

My action plans will utilize three different project categories:

1) *Unit-based Projects*: Projects where students will be introduced to a new unit using a quick design challenge such as building a device to catch a raw egg from a predetermined height and protect the egg from any damage. The students will come into class the first day of the unit with no previous knowledge of the design challenge and spend approximately half the period completing the challenge (see egg drop design challenge attached). Each of these beginning of unit challenges will be designed as a competition with clear goals. This design challenge will be referred to throughout the unit (wherever appropriate) to reinforce the concepts covered. Additionally, students will be given a unit project following the design challenge. In the case of the unit on momentum, students will then complete the egg drop project described in the documents attached. This project will be similar to the design challenge, but

with more constraints and detailed goals. Each of these projects will also include a specific focus component from the engineering design process. The idea will be to teach EDP without having to add another unit to the curriculum. These projects will be short term, consisting of only a week or two of work done mostly outside the classroom.

2) *Mini-Capstone Project*: The second project category is the mini-design project or capstone-like experience. This project will be placed at the end of the first semester, halfway through the year. Students will be expected to use all components of EDP, but will not necessarily go into deep detail with any specific step. Similar to the design challenges and unit projects, the mini-design project will also be developed as a competition with no set solution and multiple goals to achieve. Students will also present their final solution to the class and develop a report or portfolio to document their work. The timeline for this project is approximately two weeks, with some deliverables due after the first week and a presentation and competition at the end of the second week.
3) *Capstone Project*: This project is a culmination of the physics learning experience. Students are expected to apply physics principles acquired throughout the year to the design of a system, component, or process. Each project includes the development and use of design methodology, formulation of design problem statements and specifications, consideration of alternative solutions, feasibility considerations and detailed system descriptions. Projects include realistic constraints, such as economic factors, safety, reliability, maintenance, aesthetics, and social impact. Students are expected to present orally their results in a series of design reviews and students document their solutions in a written report or project notebook. A working prototype or detailed design, as appropriate, of the solution is required to complete the project. The timeline for the capstone project is approximately one full semester (second half of the year) with deliverables due every three or four weeks.

Timeline

I plan to use the three project categories differently at each level. For the college preparatory classes, I will integrate the unit projects the first year in addition to a simplified version of the mini-capstone project. At the honors level, I will implement the unit projects, the mini-capstone project, and a simplified version of the capstone project this year. All three project categories will be implemented at the AP level. Because these students are more independent and motivated, the class will provide a good test of the full EDP project progression that I would like to eventually implement at all levels that I teach. Any problems that I experience with the AP level would likely be magnified at the lower levels and indicate a need for a change.

After the first year at all levels, I hope to have determined what additional lessons and supporting materials I need to provide to my students for them to be able to successfully complete the projects and utilize the engineering design process to complete a full capstone experience. It is my new goal to bring the full capstone experience to all levels of classes I teach, first through the use of the unit projects to introduce the EDP steps, then using the mini-capstone utilize the full engineering design process in one directed project and finally through a full capstone project.

EGG DROP DESIGN CHALLENGE

Mike Graeber, Hopkinton High School, Hopkinton, MA
Josh Miranda, Revere High School, Revere, MA

OVERVIEW

In this challenge, you will design, build and test a "landing pad" which can "catch" one egg as it falls and protect it from breaking.

MATERIALS

10 sheets of copy paper
1.0m of masking tape
One pair of scissors

PROCEDURE

1. Students will have exactly 5 minutes to discuss their design plan.
2. The following will be provided to each group: 10 sheets of copy paper, 1.0m of masking tape, One pair of scissors
3. Teams will have exactly 20 minutes to build their landing pads.
4. Teams will be randomly chosen to come up to the "Drop Zone", to drop their egg.
5. There will be several drops from various heights. (0.5m, 1.0m, 1.5m, 2.0m, 2.5m) Your egg must survive lower heights to progress to the highest!
6. After each drop, you must be able to remove and show your egg to me for inspection.

Bonus points (on next Test or double if Quiz) will be awarded to teams depending on how high their egg can be dropped and still survive.

EGG DROP (MOMENTUM) PROJECT

Mike Graeber, Hopkinton High School, Hopkinton, MA
Josh Miranda, Revere High School, Revere, MA

PROJECT OVERVIEW

This project is designed to utilize your knowledge of impulse and momentum to design an enclosure/device to protect a raw egg from any damage due to a fall. Working in groups, you will use both the concepts discussed in class and implement the engineering design process steps described below.

PROJECT OBJECTIVES

In this project students will demonstrate the ability to utilize the concepts of impulse and momentum in the design of a device to solve a specific problem. In doing so, students will also perform the following steps of the engineering design process (EDP):

1. Define a problem or need (step 1)
2. Develop possible solutions (step 3)
3. Choose a best solution (step 4)
4. Build and test solution (steps 5 & 6)

PROJECT TOPIC

Problem Statement: Design and build a device or enclosure for to protect a raw egg from damage due to drops from varying heights. Your device must meet the following requirements:

1. Weigh no more than 3 lbs
2. Allow for placement and removal of egg in 30 seconds or less
3. Be reusable (for drops from multiple heights)
4. Every side of the device must be less than 30cm
5. Must protect the egg from a fall of 1 meter minimum

Any damage to the egg (even the smallest crack) will be considered a failed drop.

DELIVERABLES

To represent successful completion of this project, students will turn in the following:

- A complete egg protection enclosure/device
- A one page paper describing the engineering process you undertook, why you chose your design, the physics involved, and what you have learned from the project (individual).
- A blueprint/schematic of your final design
- Participation in a competition at the end of the project

ASSESSMENT

Because this project is a learning experience, it will not be assessed in a formal way. Instead, the aim of the project will be to complete the deliverables and engage in formal discourse around each group's work, as scientists and engineers would. This project will be given an (Exemplary) (A) grade upon full completion of the deliverables above. Additionally, extra credit will be given to the project that protects the egg from the highest drop.

Unit/Topic	**Project**
Intro	Towers, penny boats
Forces	Bridges
Kinematics	Catapult
Momentum	Egg drop
Energy	Rube Goldberg – chain reaction
Circular/rotational motion	Mousetrap car (mini capstone)
Waves/light/sound	Instrument design
Optics	Mirror maze
E&M	Electric motor
Thermo/thermal	Putt-putt boat

MOUSETRAP CAR MINI CAPSTONE PROJECT

Mike Graeber, Hopkinton High School, Hopkinton, MA
Josh Miranda, Revere High School, Revere, MA
Michael Dudley, North Central Charter Essential School, Fitchburg, MA

PROJECT OVERVIEW

This project is an introduction to the full implementation of the engineering design process and the physics concepts discussed in class so far. Students are expected to apply physics principles to the design of a system. Each project includes the development and use of design methodology, formulation of design problem statements and specifications, consideration of alternative solutions, feasibility considerations and detailed system descriptions.

PROJECT OBJECTIVES

In this project, students will use the engineering design process to design and build a mousetrap car that will move a certain required distance. As part of their research, students will use their physics knowledge up to this point to inform their proposed improvements.

PROJECT TOPIC

Problem Statement: Build a unique car that best utilizes the potential energy stored in the spring of a mousetrap. Each team will be provided one identical mousetrap to use in their design. Teams cannot alter the mousetrap in anyway (the original tripping mechanism must be used to start the motion) and must supply their own materials for the construction of the car. If you have trouble finding materials, see me for ideas. A competition will be held to determine the car the travels the greatest distance and the car that has the greatest average velocity.

DELIVERABLES

To represent successful completion of this project, students will turn in the following:

- A complete Mousetrap Car prototype (obviously).
- A group notebook outlining the completion of the design through the Engineering Design Process. This notebook should include sketches of designs, calculations, data, and group thinking about how the design work has proceeded. Your instructor may require that you answer certain questions or include certain information in each step of the EDP; this information must be included in your notebook.
- Participation in a competition at the end of the project that pits each car in the class against one another. Cars MUST be able to travel a distance of 1.21 m (4 feet).
- A “check-in” paper briefly describing the research completed, your specific goals (velocity and distance) and a sketch of you design solution and any alternative solutions considered. This paper should be one page with sketches attached.
- A final powerpoint presentation detailing your research, goals, basic calculations, alternative solutions and final design. This presentation should last approximately 10 minutes per group.

ASSESSMENT

Because this project is a learning experience, it will not be assessed in a formal way. Instead, the aim of the project will be to complete the deliverables and engage in formal discourse around each group’s work, as scientists and engineers would. This project will be given an (Exemplary) (A) grade upon full completion of the deliverables above. Additionally, extra credit will be given to the project that goes the greatest distance and the project that has the greatest average velocity in each class.

TIMELINE

The project will be completed over a two week period. At the end of the first week, teams will be required to submit the “check-in” paper described in the deliverables section. Mousetrap cars and presentations are due at the end of the two week period.

DUE DATES:

“Check-in” paper: _______________________

Final presentation and mousetrap car: ______________________

PHYSICS CAPSTONE SYLLABUS

Josh Miranda, Revere High School, Revere, MA
Michael Dudley, North Central Charter Essential School, Fitchburg, MA
28 July 2010

Project Description:
This project is a culmination of your physics learning experience. Students are expected to apply physics principles acquired throughout the year to the design of a system, component, or process. Each project includes the development and use of design methodology, formulation of design problem statements and specifications, consideration of alternative solutions, feasibility considerations and detailed system descriptions. Projects include realistic constraints, such as economic factors, safety, reliability, maintenance, aesthetics, and social impact. Students are expected to present orally their results in a series of design reviews and students document their solutions in a written report. A working prototype or detailed design, as appropriate, of your solution is required to complete the project.

Project Objectives:
The students are expected to learn and demonstrate the following abilities:
1. To solve open-ended problems,
2. To learn and effectively utilize the engineering design process to solve a real-world problem
3. Apply physics concepts and other science and math skills to implement a solution
4. To effectively communicate ideas in a written and oral format,
5. To effectively engage in scientific, peer-reviewed discourse around the presentation of their ideas;
6. To effectively work in a team,
7. Develop critical self-evaluation and risk evaluation techniques.

Project Topic:
1. Each student group is responsible for choosing their own topic and having the topic approved. The topic choice is entirely up to the group, with the following guidelines/restrictions:
2. Projects should be a solution to a non-trivial problem that improves people's everyday lives or impacts the community. Project work should be proven non-trivial through an analysis of its impact on others or on the environment.
3. Projects must be broad enough in scope (difficult enough) to warrant a half or full year of work.
4. If there is already an available solution to the problem, the project should provide a significant and needed improvement to the current solution.

Deliverables:
Each group is responsible for turning in pieces of work that serve as a documentation of their capstone. These deliverables should culminate in a portfolio that students can present in addition to their final solution.
1. A statement of the problem or need that the group wishes to resolve;
2. A research log that contains a breakdown of the following:
    - Full theoretical explanations of the physics principles that the group will need to study or use in order to understand how to solve the problem or improve a previous solution to a problem;
    - Research about how others may have gone about solving the problem;

- A full bibliography (APS format or other) that accurately cites the sources used.

3. A log of the possible solutions that have been developed by the group to solve the problem (with drawings or diagrams), and a documented determination of which solution the group wishes to pursue or build;
4. A full breakdown of the testing and evaluation of the prototype or solution, including numerical data and failure analysis if necessary;
5. Next steps that your group would take for a redesign.
6. Three design reviews (presentations) spaced throughout the project: Initial research and problem statement, possible solutions and prototyping, final design presentation
7. Final poster detailing research, prototypes, designs, and final solution

These deliverables can be turned in as a binder, a group notebook, or some other format.

Assessment:
Because this capstone project is a learning experience, it will not be assessed in a formal way. Instead, the aim of the project will be to complete the capstone and engage in formal discourse around each group's work, as scientists and engineers would. This project will be given an (Exemplary) (A) grade upon its full completion.

Timeline:
This capstone project will be completed over the course of the Spring Semester. There will be three milestone presentations that will be given by each group at different points throughout the semester. This will allow each group to account for their work and keep up with its completion. Each group will present to the class and to the instructor:

1. The problem that they to solve and the initial research about the problem, including a bibliography of sources that they found in their research (week 4);
2. The possible solutions that they have brainstormed and the solution that they chose to implement, including the method that they used to determine which solution to implement (week 10);
3. A final evaluation of the prototype, the results of any testing done with that prototype, and any proposed next steps or redesign work (week 16).